STUDIES ON RADIATION LEVEL AND RADIONUCLIDE DISTRIBUTION IN BELAGAVI DISTRICT OF SOUTH INDIA

A Synopsis of the Ph.D. Thesis

Submitted to the Mangalore University

For the Award of the Degree of

DOCTOR OF PHILOSOPHY IN PHYSICS

Submitted by

KAMALAKAR.V. DAWALEKAR

Under the supervision of

DR. Y. NARAYANA

Professor of physics

Department of Studies in Physics

Mangalore University, Mangalagangotri - 574 199

Mangalore, India

Name of the Candidate **:** Mr. Kamalakar V Dawalekar

Name of the Research Guide **:** PROF. Y. NARAYANA

Department **:** PHYSICS

Work Place **:** DEPARTMENT OF PHYSICS
MANGALORE UNIVERSITY
MANGALAGANGOTRI – 574 199

Title of the Thesis **:** STUDIES ON RADIATION LEVEL AND RADIONUCLIDE DISTRIBUTION IN BELAGAVI DISTRICT OF SOUTH INDIA

Date of Registration **:** 03/04/2018
Lett. No.: MU/EXB/Ph.D./CR.116/Phy. /2019-20/E.13 Dated 02.06.2020.

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Introduction

The natural sources of radiation to which human beings are continuously exposed to are coming from cosmic rays and naturally occurring radioactive substances found on the earth crust (UNSCEAR, 2000). The natural radioactivity in soil and rocks comes mainly from the ^{232}Th and ^{238}U decay series and natural ^{40}K. Since these radionuclides are not uniformly distributed, knowledge of their distribution in soils plays an important role in radiation protection and measurement (Ahmad et al., 2019).

The distribution of uranium on the earth's crust is related to magmatic activities during earth formation processes. The uranium has a mean abundance of continental crust is 1.3 ppm, which has a higher concentration in the upper continental crust (2.7 ppm) and interior in the lower crust (0.2 ppm) (Ballouard et al., 2018). Natural uranium is mainly constituted by ^{238}U, ^{235}U and ^{234}U created in the ^{238}U decay chain, having natural isotopic ratios 99.27% 0.730% and 0.0055%, respectively. The decay chain of ^{238}U includes 8 alpha decays and 6 beta decays respectively, often associated with gamma de-excitation of nuclei. Uranium is a trace element that occurs naturally on the earth's crust (Gradmann, 2015). All of the isotopes of uranium are unstable and are radioactive. The most abundant isotopes are ^{238}U and ^{235}U.The percentage abundance of ^{238}U is 99.25% and the abundance of ^{235}U is 0.75%. Because of its large atomic size, high valence and electro-negativity, uranium cannot form isomorphic series that involve major rock forming minerals (such as quartz or feldspar) when an igneous rock is crystallizing from a magma, and it thus occurs mostly in accessory minerals (Reitz, 2008). Some of the

accessory minerals that often contain uranium are apatite, sphene, zircon, allanite, monazite, pyrochlore, uraninite, and xenotime. Because uranium is soluble in oxidizing aqueous solutions, it is quite mobile in surface and near surface geologic materials. Surface uranium concentrations, therefore, often exhibit greater variability than potassium or thorium (Ulrich et al., 2019; Sanematsu et al., 2015).

Natural thorium has only one primordial isotope that of ^{232}Th having a natural isotopic ratio of 100%. The decay chain of ^{232}Th includes 6 alpha decays and 4 beta decays respectively often associated with gamma de-excitation of nuclei (Perkin et al., 1965). There are shorter-lived thorium isotopes in all three natural decay chains, as follows, ^{234}Th (24.1 d half-life) and ^{230}Th ($7.54x10^4$ y half-life) in the ^{238}U chain; ^{228}Th (1.9 y half-life) in the ^{232}Th chain; and ^{231}Th (1.06 d half-life) in the ^{235}U. Thorium occurs in the tetravalent (Th^{4+}) oxidation state and is insoluble except at low pH (near-neutral), or in the presence of organic compounds such as humic acids (Viers et al., 1997). Thorium is a constituent of accessory minerals as zircon, monazite, allanite, xenotime, apatite and sphene. Thorium is an element that occurs naturally on the earth's crust. The only naturally occurring isotope of thorium is ^{232}Th and it is unstable and radioactive (Salama et al., 2021). According to thorium is chemically stable in the tetravalent ion state under reducing conditions, has a large ionic radius, a high coordination number (8) with respect to oxygen, and complete outermost electron shells (Mernagh & Miezitis, 2008). Because of its large atomic size, high valence and electron negativity, thorium cannot form isomorphic series that involve major rock forming minerals and occurs mostly in accessory minerals. Under oxidizing conditions, thorium remains stable in the tetravalent state and is not soluble in aqueous solutions. Some of the accessory minerals that often contain thorium are apatite, sphene, zircon, allanite, monazite, pyrochlore, thorite, and xenotime (Bateman & Catt, 1985). ^{232}Th concentration in biological materials is negligible due to its relative insolubility compared to radium and its low specific activity. Thorium has been found

to be present in the highest concentration in pulmonary lymph nodes and lungs indicating that the principal source of human exposure is inhalation of suspended soil particles, (Keith et al., 2019).

Potassium **(**^{40}K) has an isotopic abundance of 0.0118 % and a half-life of 1.248 x 10^9 years (NNDC/ENSDF, 2015). The natural Potassium abundance in various rock types is from 0.3 to 4.5 %. Its contents in certain basalts and sands are low compared to granites and other basalts (Abdalrahman, 2012). Potassium is a major element widely distributed in crustal rock, for instance calcium rich granites may contain up to 2.5 % of potassium (Zhao et al., 2019). In crystal rocks, its mean activity is 0.62 Bq g^{-1}, with basalt averaging about 50 % this amount while in soil; it has a mean minimum activity concentration of about 0.44 Bq g^{-1} (Maguire et al., 1993). The concentration of ^{40}K in soil can be appreciably altered by agricultural activities, especially through the application of potassium bearing fertilizers which have been observed to increase the potassium content of soil under cultivation (Sannappa et al., 2010). Potassium is an essential element needed by plants and animals, and ^{40}K is an important human internal and external radiation source, with a specific activity of 31.4 Bq g^{-1}. On the earth's crust, potassium is widely distributed, with concentrations ranging from about 0.1 % for limestone to more than 4 % for some granite (Turekian et al., 1967). Potassium (^{40}K) is found in all biological systems, which is primarily irradiate the respiratory tract, the predominant source of internal dose from NORM from the decay of ^{40}K. Natural potassium has three isotopes, and the only unstable isotope is ^{40}K. Potassium occurs in major minerals such as feldspar and micas (Das & Pradhan, 2016)

The several natural radioelements belonging to natural uranium series, ^{210}Po and ^{210}Pb have been considered important either for their toxicological significance or for their special accumulation behavior in the environment (Parfenov et al., 1974). Both ^{210}Pb and ^{210}Po easily enter the human body. Consumption of food is usually the most important route by which these

radionuclides enter the human organs. The radionuclide ^{210}Pb is a bone seeker and is found incorporated in bone mineral from where it seems to be eliminated by long term skeletal remodeling (Ziegler et al., 1996). ^{210}Po in contrast is not a bone seeker but is rather distributed in soft tissues after intake. ^{210}Po decays with a half-life of 138.4 days by alpha emission (5.3 MeV). Therefore, ^{210}Po causes considerably greater biological damage compared to beta emitter ^{210}Pb. It is estimated that the equivalent dose resulting from a single disintegration of ^{210}Po is thousands time greater than ^{210}Pb decay.

Radon is a natural radioactive gas that occurs everywhere in the world. Radon is a chemical element with symbol Rn and atomic number 86. It is a radioactive, colorless, odorless, tasteless noble gas occurring naturally and not detectable by human senses alone. When ^{226}Ra decays by alpha emission, it transforms to ^{222}Rn, a radioactive gas with half-life of 3.8 days. Radium in the soil is the main source of radon present in the atmosphere. The radon gas exhaled from the earth's surface into free space is rapidly dispersed and diluted by vertical convection and turbulence (Shahbazi et al., 2013, Monged et al., 2020). Radon and thoron present in outdoor and indoor air as they exhaled from soil and building materials. It is observed that inhalation of radon and their progeny concentrations has been shown experimentally, to cause lung cancer in men exposed for long time to such air. The measurement of radon, thoron and their progeny concentrations also lead to the knowledge of the presence of radioactive elements. Radon can move more rapidly through permeable soils such as coarse sand and gravel than through impermeable soil such as clays. Radon can move through cracks in rocks and through pore spaces in soils. Basic sources of radon are rocks, soil, ground water and building materials (Schwardon, 2010). In India measurement of radon and thoron concentrations have been done for the past many years which were undertaken by Environment Assessment Division, Bhabha Atomic Research Centre and some of the universities. Many techniques are in use to measure the radon, thoron levels in air and soil. Many types of

dosimeters employing tracks detection have been developed. The nuclear track detector technique is the most reliable method. Fault region also plays important role in the out-gassing process of radon and thoron from soil. Radon's primary pathway is from the earth through the basements of houses and other buildings and into air that people breathe. The present work will help in understanding the status of indoor and outdoor radon, thoron and their progeny concentrations. In this experimental work, indoor concentrations are measured by using Solid State Nuclear Track Detector (SSNTD) (UNSCEAR, 1982).

Study area

The Belagavi district is one of the largest districts of Karnataka state in India, which is located on the eastern part of the Western Ghats by acquiring an area of 13,444 square kilometres. The north latitude of the district from 15°00' to 17°00' and east longitude is 74°00' and 75°30'. The district of Belagavi is rich in natural mineral resources with iron ore, manganese, bauxite, clay and limestone. As per Geograrphical Survey report of Belagavi, the climate of their region is semi arid (Prabhavati et al., 2015). The mean temperature varies from 27 °C to 35.7 °C during the year, while the minimum temperature varies from 13.9 °C to 20.6 °C. Winters are pleasant, and summers are hot and dry in the district. The maximum temperature normally found in the months of March to May up to 35.7 $^{\circ}$C. Some part of the Belagavi district comes under semi malanad region, therefore the average rainfall is 808 mm. The major types of soil found in the study area are shallow black soil, medium black soil, deep to very deep black soil, mixed red black soil, red loamy soil, lateritic soil, and alluvial soil. The important minerals found in the study area are, Bauxite ore which generally occur as irregular pockets within a length of few a kilometers. The parent rocks in this region weathered to soils of heterogeneous properties such that within a hectare of land different units of soil may be

found. Apart from that Building stone, ordinary clay and grey granite C are readily available in this district.

Aim and Scope

Human beings are subjected to radiation exposure due to natural background radiation, which comprises of cosmic radiation and terrestrial radiation. Natural radioactivity is wide spread in the earth's environment and it exists in various geological formations in soil, plants, water and air (Klement, 1982). Uranium is a naturally occurring radioactive element present in trace amounts throughout the earth's crust. The radioactive elements of Uranium and Thorium series contribute significantly to the terrestrial radiation exposure. The decay of NORM produces gamma-beta radiation field in soil, which in turn crosses the soil-air interface and results in terrestrial radiation exposure to human beings (Reddy et al., 1983). Since NORM is one of the main sources of human exposure. The radiation dose from the natural radiation exposure and their effects on human health would improve the understanding of damaging of cells by the radiation. Therefore, the effect of physico-chemical properties of radio elemental distribution has been examined by using standard protocols. This plays a major role in determining the behavior of radionuclides present in it. Radon is a progeny of uranium decay series formed from radioactive decay of radium in the environment, soil, groundwater, oil and gas deposits and is the primary source of naturally occurring α-radiation present everywhere in the environment in varying concentration (Nazaroff, 1988). The higher radon level in soil can be ingested or inhaled will result in exposure of human organs to radiation, primarily lungs (ICRP 1975).

As a result, the progressive development of the above said scientific, technological and industrial activities make it absolutely necessary to evaluate the background of natural radiation and radioactivity in the environment in order to detect humanly manufactured contamination, assess its impact, and implement appropriate countermeasure to protect the population and the

environment. At the same time, since natural radiation is the main source of human exposure, studies on the dose from this source and it effects on health, improve the understanding of radiation damage and, therefore, are of great value as a reference, when standards and regulatory control action on radiation protection are established.

The present study aims to assess the concentration of ^{226}Ra, ^{232}Th, ^{40}K in the soil samples in the environment matrices of Belagavi district, Karnataka, India. It is important to assess the radiation hazard arising due to use of this soil samples which could be used as building construction materials and which results in the internal and external exposure to the occupants. This baseline information is necessary in order to evaluate the distribution of terrestrial radionuclide and radiation dose likely to be received by population inhabiting in that area. The indoor radon and thoron in dwelling were carried out using SSNTD pin hole dosimetry cup technique. The internal dose to the human organs, such as lungs has been estimated. The ^{210}Po and ^{210}Pb in soil samples were analyzed using radiochemical deposition method. The ^{210}Po causes greater biological damage to the human body due to it transfer through the aerosol attachment and through food chain. The results were compared with the data reported for other environs. It also provides the importance of multivariate statistical tools in routine monitoring of trace element in the region. Hence, it is important to understand the basic dynamics of radionuclides, trace element, and indoor radon and thoron in the environmental samples of Belagavi district.

Objectives of the study

- Measurement of gamma dose rate in air and Evaluation of hazard due to radiation and trace element to the population of the region of Belagavi district.
- Distribution of natural radionuclides ^{226}Ra, ^{232}Th, ^{40}K, and physico-chemical parameter in soil of Belagavi district.

- Studies on indoor Radon, Thoron concentration levels in the environs of the region and evaluation of lung dose rate to human population.
- Assessment of outdoor radon concentration and lung dose rate in Belagavi district of Karnataka, India.
- Studies on distribution of polonium (^{210}Po) and lead (^{210}Pb) activity concentration in undisturbed sandy clay soil in Belagavi region, Karnataka, India.

Measurement of the activity concentration of, ^{238}U, ^{232}Th and ^{40}K in soil of Belagavi district, Karnataka in south India, was carried out using gamma ray spectrometer and the correlation between the radionuclides ^{238}U, ^{232}Th and ^{40}K and physico-chemical parameters of the soil were studied. The radiological parameters such as absorbed dose rate (D), radium equivalent activity (R_{aeq}), external and internal hazard index (H_{ex}, H_{in}), annual effective dose equivalent (AEDE), and gamma index (I_g) were measured.

Methodology

- In the present study the GM tube based Polimaster (PM1405) gamma ray survey meter is used to measure the ambient gamma dose rate in air.
- The sampling locations were identified based on geographical of the study area. The soil, and indoor, outdoor radon samples were collected in the region following the EML standard procedures (EML, 1983).
- The collected soil samples were brought to laboratory for further processing. The soil samples were dried in air circulated oven and sieved through 250 µm mesh. The sieved soil samples were stored in 250 ml container to obtain secular equilibrium between radionuclides and its progeny.

- In the present study, the activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K in the soil samples is studied using a NaI (Tl) detector gamma spectrometry. The spectrometer efficiency and energy were calibrated using the IAEA standard sources.
- Pin hole dosimeter cup with LR-115, and SSNTD used for the measuring the indoor and outdoor radon and thoron concentration in the study area.
- The activity concentration of ^{210}Po was estimated by radiochemical separation and subsequent deposition on a silver disc. The disc was then counted on both sides using a ZnS (Ag) alpha counter having an efficiency of about 30%. The activity of ^{210}Pb was estimated through ^{210}Po by allowing the ^{210}Po plated solution for a period of 12 months to build up the ^{210}Po from ^{210}Pb.
- In the present study the FTIR spectrometry was used to analyse the mineralogical composition in the soil samples. The standard values were used to identify the minerals by comparing the transmittance spectra of the soil samples.
- Multivariate statistical analysis was used to find the interrelation among the parameters obtained from the soil samples. In the present investigation, the statistical software 'Statistical Program for the Social Science (SPSS)' was used for the statistical analysis, pearson correlation, cluster analysis, principal component analysis studies.

Thesis Outline

Natural radioactivity is one of the leading causes of radiation dose being administered to the human beings and so it becomes a potential risk for them. The concern regarding natural radioactivity grows with more and more knowledge of damaging effects of these radiations to

the living things. In the current scenario many government agencies of different countries are taking responsibility to tackle with this problem. The thesis entitled “Studies of Radiation Level, Radionuclide Distribution and Trace Elements in Belagavi District of South India” is a detailed account of the measurements of ambient radiation level and radionuclides distribution, physico-chemical parameters in soil and also, the radon, thoron and their progeny levels in dwellings in various locations of of Belagavi district, South India.

The thesis is divided into six chapters.

Chapter 1

Provides a general introduction to the problem of natural radioactivity. A brief history of natural radioactivity and its various units are given. Basics of Uranium, Thorium and Potassium and its decay series of radionuclides and radon, its properties and its sources are explained. The health effects of radon, thoron and progeny have also been discussed.

Chapter 2

A detailed review of literature has been given related to the present investigations. The findings of several works done throughout the world and data associated it. And the study area has been discussed extensively for radon concentration and annual effective dose received by the inhabitants. The literature regarding the health effects of the radon, thoron and their progeny concentration has also been discussed thoroughly.

Chapter 3

Details of the instruments like gamma survey meter, alpha counting system, NaI (Tl) gamma ray spectrometer, spark counter, and FTIR are the experimental techniques for the measurements of natural radioactivity in soil, indoor radon, thoron and their progeny

concentration have been discussed. Radiochemical methods and a scintillation-based alpha counting system were used to measure the radionuclides ^{210}Po and ^{210}Pb. The twin cup dosimeter technique and the newly developed pin hole dosimeters technique have been used for the measurements. The spark counting technique for the counting of the alpha particle tracks registered in the solid-state nuclear track detectors has been discussed in this chapter. The techniques for the measurements of bulk etch rate and track sensitivity have also been discussed. The detailed working of the techniques presently used has been discussed for the understanding of the underlying principles of present study.

Chapter 4

This chapter includes the results and discussion of gamma absorbed dose rates in the air, the distribution of ^{40}K, ^{226}Ra and ^{232}Th radionuclides in soil and dependence of physico-chemical properties of these radionuclide concentrations. The ^{210}Po and ^{210}Pb in soil samples were analyzed using radiochemical deposition. The radiological hazards are studied and reported in this section. The results are analysed using appropriate statistical tools. The results of the activity concentration of radionuclides in environs and the resultant dose to the population of the region are discussed in this chapter.

The values of indoor radon, thoron and their progeny have been reported for the Belagavi district. For checking the effects of season, the seasonal measurement has also been made for Belagavi district using twin cup dosimeters technique. The techniques used reveal that there are more indoor radon levels in poorly ventilated houses and hence it is important that the dwellings should have good ventilation conditions to avoid any harmful effects of this natural gas “Radon”. The values of average indoor radon values and annual effective dose of the whole study area have been compared with the values reported for other environs.

Chapter 5

Important conclusions drawn from the present investigations are summarized and suggestions for future studies are given in this chapter.

(Y Narayana) (Kamalakar V Dawalekar)

Research Guide Research Student

Date: Date:

References

Abdalrahman, H. E. K. (2012). Assessment of absorbed dose rate from terrestrial gamma radiation in Red Sea State.

Ahmad, A. Y., Al-Ghouti, M. A., AlSadig, I., & Abu-Dieyeh, M. (2019). Vertical distribution and radiological risk assessment of 137Cs and natural radionuclides in soil samples. *Scientific reports*, *9*(1), 1-14.

Ballouard, C., Poujol, M., & Zeh, A. (2018). Multiple crust reworking in the French Armorican Variscan belt: Implication for the genesis of uranium-fertile leucogranites. *International Journal of Earth Sciences, 107(7), 2317-2336.*

Bateman, R. M., & Catt, J. A. (1985). Modification of heavy mineral assemblages in English coversands by acid pedochemical weathering. *Catena, 12(1), 1-21.*

Das, I., & Pradhan, M. (2016). Potassium-solubilizing microorganisms and their role in enhancing soil fertility and health. *In Potassium solubilizing microorganisms for sustainable agriculture (pp. 281-291). Springer, New Delhi.*

Eisenbud M and Gesell T F., (1997). Environmental radioactivity from natural, industrial and military sources*: from natural, industrial and military sources (4th edition). London: Academic Press.*

Gradmann, M. (2015). Radioanalytical separation and measurement techniques for uranium in environmental samples *(Doctoral dissertation, Master thesis, institute of earth and environmental sciences, albert-ludwigs-universität Freiburg).*

J. F. Ziegler, (1996) "Terrestrial cosmic rays," in *IBM Journal of Research and Development, vol. 40, no. 1, pp. 19-39, Jan. 1996, doi: 10.1147/rd.401.0019.*

Jaworowski, Z., (1967). Stable and radioactive lead in environment and human body (No. NEIC-RR-29). *Institute of Nuclear Research, Warsaw (Poland).*

Keith, S., Wohlers, D., & Ingerman, L. (2019). Toxicological profile for thorium.

Stellmer, S., Kazakov, G., Schreitl, M., Kaser, H., Kolbe, M., & Schumm, T. (2018). Attempt to optically excite the nuclear isomer in Th 229. *Physical Review A, 97(6), 062506.*

Klement, A. W. (1982). Natural sources of environmental radiation. *Handbook of Environmental Radiation, 1315-1317.*

Maguire, C. S. (1993). Natural and anthropogenic radionuclides in organic and mineral soils. University of Glasgow (United Kingdom).

Mernagh, T. P., & Miezitis, Y. (2008). A review of the geochemical processes controlling the distribution of thorium in the Earth's crust and Australia's thorium resources *(p. 48). Geoscience Australia.*

Monged MHE, Abu Khatita AM, & El-Hemamy ST, (2020). Environmental assessment of radioactivity levels and radiation hazards in soil at North Western-Mediterranean Sea coast, Egypt. *Environmental Earth Sciences. 79:1–14. https://doi.org/10.1007/s12665-020-09131-y.*

Narayana, Y., Rajashekara, K.M., & Siddappa, K. (2007). Natural radioactivity in some major rivers of coastal Karnataka on the southwest coast of India. *Journal of Environmental Radioactivity, 95(2-3), 98-106.*

Nazaroff, W. W., Nero, A. V., (1988). Radon and its decay products in indoor air.

NCRP. National Council on Radiation Protection and Measurements, (1975). Natural background radiation in the United States, *NCRP Rep. No 45, Bethesda, Maryland*

Parfenov, Y. D., (1974). Polonium-210 in the environment and in the human organism. *Atomic Energy Review. 12(1), 75-143.*

R. Fukai and Y. Yokoyama, Natural radionuclides in the environment. *The Natural Environment and the Biogeochemical Cycles.* (Springer, Berlin, Heidelberg, 1982).

Reedy, R. C., Arnold, J. R., & Lal, D. (1983). Cosmic-ray record in solar system matter. *Annual Review of Nuclear and Particle Science, 33(1), 505-538.*

Reitz, G. (2008). Characteristic of the radiation field in low Earth orbit and in deep space. *Zeitschrift fur Medizinische Physik, 18(4), 233-243. https://doi.org/10.1016/j.zemedi.2008.06.015*

Salama, A., & Mohmaed, A. (2021). Impact of Technologically Enhanced Naturally Occurring Radioactive Materials (TE-NORM) In oil and gas industry On Environment. *Assiut University Bulletin for Environmental Researches, 24(1), 23-34.*

Sannappa, J., Ningappa, C., & Narasimha, K. N. (2010). Natural radioactivity levels in granite regions of Karnataka State. *http://hdl.handle.net/123456789/10487*

Sanematsu, K., Kon, Y., & Imai, A. (2015). Influence of phosphate on mobility and adsorption of REEs during weathering of granites in Thailand. *Journal of Asian Earth Sciences, 111.*

Schwadron, N. A., Boyd, A. J., Kozarev, K., Golightly, M., Spence, H., Townsend, L. W., & Owens, M. (2010). Galactic cosmic ray radiation hazard in the unusual extended solar minimum between solar cycles 23 and 24. *Space Weather, 8(5).*

United Nations Scientific Committee on the Effects of Atomic Radiation. (2000), Sources and Effects of Ionizing Radiation, *UNSCEAR 2000 Report Vol.1 to the General Assembly, with scientific annexes, United Nations Sales Publication, United Nations, New York.*

UNSCEAR, (1982). United Nations Scientific Committee on the effects of atomic radiation. Annex B: *Exposures from natural sources of radiation paragraph 87 p 17.*

UNSCEAR, (2010). Sources and Effects of Ionizing Radiation: Report to the General Assembly, *with scientific annexes, vol 1 (United Nations, New York). 1-219.*

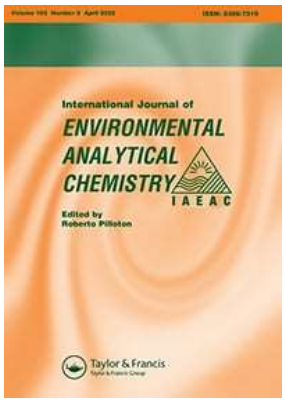
Zhao, T., Cawood, P. A., Wang, K., Zi, J. W., Feng, Q., Nguyen, Q. M., & Tran, D. M. (2019). Neoarchean and Paleoproterozoic K-rich granites in the Phan Si Pan Complex, north Vietnam: *Constraints on the early crustal evolution of the Yangtze Block. Precambrian Research, 332, 105395.*

List of Publication

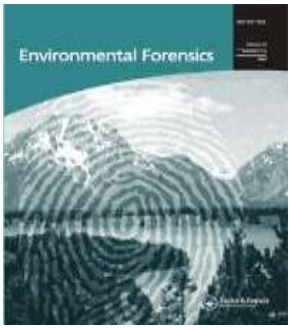
In Peer-reviewed Journals

[1]

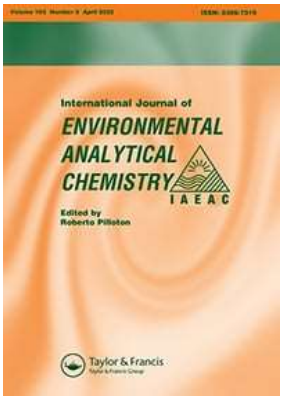
Kamalakar V D, Vinutha P R, Kaliprasad C S & Narayana Y (2022) "Seasonal variation of indoor radon, thoron and their progeny concentration in dwellings of Belagavi district, Karnataka state, India" *Environ Monit Assess (2022) pp 194:310 https://doi.org/10.1007/s10661-022-09931-8.*

[2] 

Kamalakar V D, Vinutha P R, Kaliprasad C S & Narayana Y (2022) "Radiation level, radionuclides distribution and minerals concentration in soils of Belagavi district of Karnataka, India" *INTERNATIONAL JOURNAL OF ENVIRONMENTAL ANALYTICALCHEMISTRY, 17Jan2022 https://doi.org/10.1080/03067319.2022.2027932.*

[3] 

Kamalakar V D, Vinutha P R, Kaliprasad C S & Narayana Y (2022) "Distribution of radionuclides and physico chemical parameter in soil of Belagavi district, Karnataka, India" *International journal Environmental forensic* https://doi.org/10.1080/15275922.2022.2125113.

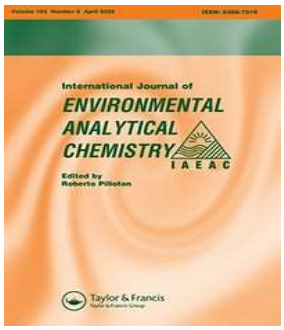
[4] 

Lokesh N, Vinutha P R, **Kamalakar V D** & Narayana Y (2022). Assessment of natural radioactivity and its dependence on clay minerals of the soil of Dakshina Kannada district, South India. INTERNATIONAL JOURNAL OF

ENVIRONMENTAL ANALYTICALCHEMISTRY, 10 Aug 2022, https://doi.org/10.1080/03067319.2022.2107922

[5]

Kamalakar V D, Vinutha P R, Sandesh Achari, & Narayana Y (2022). Studies on distribution of 210Po and 210Pb activity and physico chemical effects of undisturbed alluvial clay soil in Belagavi district, Karnataka, India. *RSC conference (Paper accepted for publication)*

[6] 

Kamalakar V D, Vinutha P R, & Narayana Y (2022) "Studies of outdoor radon and its dependence of radium content in soil in the environs of Belagavi, Karnataka, India" *INTERNATIONAL JOURNAL OF ENVIRONMENTAL ANALYTICALCHEMISTRY*, (Revision).

[7]

Kamalakar V D, Vinutha P R, & Narayana Y (2022) "Studies on distribution of ^{210}Po and ^{210}Pb activity concentration in undisturbed sandy clay soil in Belagavi district, Karnataka, India" *Analytical methods journal (Communicated).*

In Symposia / Conference

1. **Kamalakar V D**, Kaliprasad C. S & Narayana Y (2020). "Natural radioactivity in soils of Belagavi district in Karnataka" *2nd International conference on Sustainable urban*

development, resource conservation and food security (SURF-2020), Bearys knowledge campus, Mangalore. August 6-8, 2020.

2. **Kamalakar V D**, M.M. Prakash & Y Narayana (2021). "Assessment of outdoor radon concentration in Belagavi district, Karnataka, India". *21st National Conference on Solid State Nuclear Track Detectors and Their Applications (SSNTDs-21)" hosted by Ramjas college, Delhi. 29-31 January, 2021.*

3. **Kamalakar V D**, Kaliprasad C. S & Narayana Y (2021). "Studies on natural radioactivity and physico-chemical parameters of soil in Belagavi, India" *Radiation Awareness and Detection in Natural Environment (III RADET), TehriGarhwal, March 18-20, 2021.*

4. **Kamalakar V D**, Vinutha P R, Sandesh Achari, & Narayana Y (2022). Studies on distribution of ^{210}Po and ^{210}Pb activity and physico chemical effects of undisturbed alluvial clay soil in Belagavi district, Karnataka, India. *RSC conference Sep 2022, London, UK.*

5. Lokesh N, **Kamalakar V D**, & Narayana Y (2021). "Studies on indoor radon-thoron concentration in dwellings of Dakshina Kannada district of Karnataka state, India" *Radiation Awareness and Detection in Natural Environment (III RADET), TehriGarhwal, March 18-20, 2021.*

6. Lokesh N, **Kamalakar V D**, Kaliprasad C S & Narayana Y (2021) "Distribution of natural radionuclides in the rocks of Dakshina Kannada District, Karnataka" *21st National Conference on Solid State Nuclear Track Detectors and Their Applications (SSNTDs-21)" Ramjas college, Delhi. 29-31 January, 2021.*